

# **Hydrodynamic Stresses Driving Pore Pressure Changes in Sandy Coastal Sediments**

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## **LONG-TERM GOALS**

The project goals are two-fold: to 1) quantify the ambient and dynamic pore water pressures and pore water pressure changes in selected coastal sediments and 2) measure other environmental parameters including water column and sediment properties in support of a NATO Mine Burial modeling study. An important aspect of the work is the quantification of the first order forces responsible for the dynamic bottom pressures and pore pressure behavior in sandy seafloor sediments in response to wave-induced bottom stresses.

## **SCIENTIFIC OBJECTIVES**

Objectives of the Phase II (FY-98) field exercise were to collect environmental and sediment properties data in support of the NATO Mine Burial Modeling effort for prediction and evaluation of liquefaction and scour. In addition to the pore pressure measurements collected with a multi- piezometer probe, numerous in situ electrical conductivity measurements provided a statistically reliable sediment property database of porosity, void ratio, wet bulk density and dry bulk density. Sediment sampling with cores and grabs by other participants provided material for detailed grain size analyses and other sediment property tests. Sediments were fine to medium sand. The test site was the same area as the 1997 Phase I experiment (designated as area C—1) conducted in water depths of ~15 meters ( ± tidal changes) off the coast of Holland.

## **APPROACH**

The NATO Phase I and II investigation is an in situ high resolution field instrumentation approach using a Multi-Piezometer Array System (MPAS), electrical conductivity probe techniques and the Woods Hole Oceanographic Institution (WHOI) BASS instrumentation. The BASS provided environmental measurements including wave induced bottom pressures, current velocity, turbidity, and conductivity.

## **WORK COMPLETED**

Prior to the Phase II field exercise and following the Phase I field work, the MPAS underwent a thorough engineering evaluation and the system was tested and reconditioned with available parts. Software changes were made following Phase I and calibrations were completed. The MPAS consists of 12 piezometer probes each having 6 pressure transducers that measure the free-water column and sediment pore water pressure (three sensors).

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The Bass Tripod and MPAS were deployed in the C-1 area and data were collected for approximately a three-week period in November 1997. The systems were recovered the first part of December. Details of the NATO Phase I exercise and instrumentation are found elsewhere (Bennett 1997 and Bennett et al., 1997).

## **RESULTS**

- **WHOI BASS Tripod:** The Woods Hole Oceanographic Institution (WHOI) Benthic Acoustic Stress Sensor (BASS) tripod was successfully launched and recovered for a three-week period. Contemporaneous measurements included the vector-flow velocity, temperature, optical-back scatter, conductivity and pressure. To enable rotation of sensor vector measurements into earth coordinates, tripod tilt, roll, and magnetic heading were recorded.
- **Multi-Piezometer Array System (MPAS):** Eight probes were deployed in a specified array. Data were recovered from one probe for approximately a three-week period.
- Quality bottom pressures, current velocity, turbidity, and conductivity data were collected with the BASS for the duration of the experiment. Significant surface-wave induced bottom pressure amplitudes were recorded with MPAS and subbottom pore pressures amplitudes were measured to depths of 21 cm below the sediment-water interface. Electrical conductivity measurements were achieved to subbottom depths of approximately 45 cm at eight stations. These measurements provided in situ sediment physical properties data for comparison with tests made on core samples. Selected special laboratory tests were made on sediment samples for the determination of maximum and minimum porosity and wet bulk density. The data were useful for the understanding (estimating) the range of selected physical property values possible for the sediments from the C-1 test area.
- Bottom sediments were analyzed for selected physical properties. Sediment grain size was completed on selected core and grab samples provided by the Dutch participants. X-ray diffraction measurements (compliments of Dr. B. Ransom, SCRIPPS) of sediment collected from deposits found on the MPAS revealed the material to be quartz, calcite, and albitic plagioclase feldspar that was periodically enhancing the turbidity of the water column as a result of dredge material dumped near the C-1 area.

## **IMPACT/APPLICATIONS**

The coupling of an object (mines, platforms, pipe lines, etc.) with the seabed and the combined dynamic interaction in response to hydrodynamic forcing is largely governed by the influence of waves and currents and the nature of the seabed materials. The processes are complex and reliable predictive capabilities (models, numerical formulations and quantitative estimates) must consider the combined effects of water-column-seabed dynamics and the time dependent changes in their properties. Time constants for the dynamic behavior of the sediment vary significantly for sands, silts, clays and admixtures, and depend upon the nature and duration of the environmental forcing and upon the fundamental nature of the sediment properties (Mei and Foda, 1981, Bennett et al. 1982, 1992a and

b). The environmental measurements, sediment data, and in situ electrical conductivity and pore pressure databases will provide important input parameters required for the testing and evaluation of existing mine burial models. This has significant application to virtually all shallow-water coastal sediments and regions that are important to a variety of U.S. Naval activities.

## **TRANSITIONS**

The project is providing environmental data, in situ sediment and water column measurements (BASS), laboratory sediment analyses, and crucial data on the time-dependent pore pressure changes within a sandy sedimentary deposit. These data are important to studies of marine sediment stability, scour and liquefaction, strength changes, effective stress state, and the development of pore fluid gradients through the sediment-water interface which directly affect mine burial, buried mine performance, and environmental assessment.

## **RELATED PROJECTS (NOT APPLICABLE)**

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Mei, C.C. and M.A. Foda., 1981. Wave-Induced Responses in a Fluid-Filled Poro-Elastic Solid with a Free Surface: A Boundary Layer Theory, Geophys. Journ, Astron. Soc., Vol. 66, pp.597.

## **PATENTS**

September 8, 1998 - Patent award number 5804715, "Hydrodynamic Dampening System For The Precise Measurement Of Dynamic Sediment Pore Water Pressure"

June 1998 - C.A. Hogentogler Award established by ASTM Committee D-18 on Soil and Rock, for paper on "A Multi-Sensor Piezometer for Shallow Marine Sediments in Coastal Environments"